SMOKE PROBLEM IN 20 VAD SYSTEM: THE EFFECT OF FLASH SUPPRESSANT AND ANTIFOULANT PROPELLANT ADDITIVES

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BY

A. VICTOR NARDI

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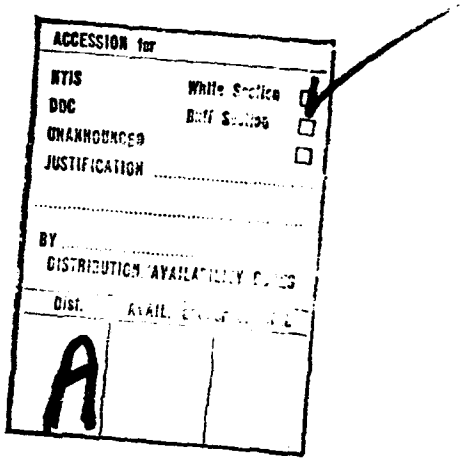

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ABSTRACT

The testing of specially manufactured lots of propellant with reduced amounts of flash suppressant and antifoulant indicated that smoke can be reduced and, therefore, the behind-the-gun visibility can be improved. However, propellant without flash suppressant cannot be used in the present 20 mm, M168, VAD system gun which is not equipped with a mechanical flash hider.

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INTRODUCTION

The Weapons Command has complained of smoke occasionally obscuring the target when the 20 mm Vulcan Air Defense System (VADS) is fired.[1] The propellant used in the VADS was originally developed for ammunition fired in the M39 and M61 aircraft gun systems. No smoke problem would be expected in a gun system firing from a moving aircraft. Studies have shown that the major portion of gun smoke is derived from: the projectile wear; the primer; the propellant flash suppressant; and, in the case of the standard 20 mm M50 series propellant (WC 870) the antifoulant.[2] A the present time no way is known to eliminate the smoke caused by the projectile. Research has shown a method of eliminating the smoke caused by the primer, but an extensive primer development program would be required.

Therefore, an attempt was made to reduce the smoke caused by the propellant additives.[3,4] The method employed was to reduce or completely eliminate, if possible, both the flash suppressant and the antifoulant from the propellant. Two propellant types were selected for smoke and flash tests: (1) WC 870, the standard ball type; and (2) CR 7814, an extruded type, which was being evaluated as an alternate propellant for the 20 mm M50 ammunition series. In the case of the WC 870 ball propellant, the flash suppressant (which also aids in ignition) and the antifoulant are coated on the outside of the propellant grain. However, in the CR 7814 extruded propellant, the flash suppressant and the antifoulant are incorporated in the base grain, see Table I.

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[1] Teletype No. RI 33379 dated 27 September 1966, from Weapons Command to Munitions Command.

[2] "Smoke and Flash in Small Arms Ammunition," September 1954, Midwest Research Institute, Contract DA 23-072-ORD-769.

[3] Letter from Frankford Arsenal to US Army Munitions Command, "Smoke Problem in 20 mm VAD System," dated 18 November 1966 with 1st Ind to US Weapons Command dated 12 December 1966.

[4] Procurement/Work Directive from US Army Weapons Command to Frankford Arsenal, "Chaparral/Guns," AMCMS Code 5292.12. 69702.25 dated 3 January 1969.

TABLE I

Flash Suppressant and Antifoulants

Propellant	Flash Suppressant	Antifoulant
WC 870 (ball)	Potassium nitrate	Tin dioxide
CR 7814 (extruded)	Potassium sulfate	Tin

An additional smoke and flash test was performed with a special lot of extruded propellant without antifoulant.

PROPELLANT AND AMMUNITION FOR SMOKE AND FLASH TESTS IN VAD SYSTEM

It appeared that an optimum initial program would be to manufacture three lots of each type of propellant. Information obtained from Olin Corporation, the commercial producer of WC 870 propellant, indicated that the amount of potassium nitrate in recently manufactured lots varied between 0.71 and 1.05 percent and the amount of tin dioxide between 0.71 and 0.98 percent. It was expected that the amount of potassium sulfate and tin in CR 7814 propellant would vary in the same general range. Based on the above ranges for the production of propellants, it was agreed that the three special samples of each type of propellant would be as follows:

Sample No. 1 would contain 0.5 percent flash suppressant and 0.5 percent antifoulant;

Sample No. 2 would contain 0.25 percent suppressant and 0.25 percent antifoulant;

Sample No. 3 would contain no flash suppressant or antifoulant.

At the present time there is no attempt to closely control the amount of these additives in production propellant; however, in the manufacture of these samples the amount of the additives was controlled as closely as processing would allow.

The special samples of WC 870 type ball propellant were manufactured by Olin Corporation at the presently dismantled East Alton

plant and the CR 7814 extruded type samples were produced by E. I. DuPont de Nemours & Company at their Carney's Point Works. When the six samples were delivered to Lake City Ammunition Plant (LCAAP) they were loaded into 20 mm M55A2 cartridges. Two control lots were also loaded, using the same lots of metallic components. One control was loaded with standard WC 870 AL 45730 ball propellant manufactured at Badger Army Ammunition Plant (BAAP)(Olin Corp was the contractor operator) and the other with CR 7814 Lot 4, extruded propellant previously manufactured by DuPont for the alternate propellant engineering test at LCAAP. [5] Table II lists the test lots of loaded 20 mm M55A2 ammunition, together with the propellant description.

Ballistic tests were fired at LCAAP with the eight lots of 20 mm ammunition before shipment to Aberdeen Proving Ground (APG). Velocity, pressure, and action time were recorded after storing the ammunition at +70°, -65° and +165 °F. The results of these tests are reported in Table III.

Review of the ballistic data contained in these tables indicates the six lots of ammunition loaded with the experimental propellants, and the two control lots to be satisfactory for shipment to APG for the smoke and flash tests.

SMOKE AND FLASH TESTS

Aberdeen Proving Ground

The eight special lots of 20 mm, M55 ammunition loaded at LCAAP were tested for smoke and flash at APG. The detailed results of the smoke tests are reported in reference 6, which contains photographs of smoke evaluation setup for the 20 mm M168 gun used during these tests. The M168 gun is identified as the M163 system when it is a self-propelled unit and as the M167 system when it is a towed unit.

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[5] A. Victor Nardi, "Smoke Problem in 20 mm VAD System," Frankford Arsenal Quarterly Progress Reports from 4 April 1969 to 6 March 1973.

[6] Mr. Hartung, "Engineer Design Test of Propellant for 20 mm Cartridge for Vulcan Air Defense System," USA Tecom Proj No. 3-MU-005-000-001, Report No. APG-MT-3818, April 1971.

TABLE II

Description of Propellants Loaded Into Cartridges, TP, 20 mm, M55A2 With M54A3B1 Primers

Ammunition Lot Number	Manufacturer	Type	Propellant Lot Number	Calcium Carbonate (%)	Sodium Sulfate (%)	Potassium Nitrate (%)	Tin Dioxide (%)	Potassium Sulfate (%)	Tin (%)
			First Smoke and Flash Test at APG						
IED 70-15-C	Olin Corp	Ball	WC 870 AL 45730	0.09	0.33	0.95	1.11	--	--
IED 70-15-68	Olin Corp	Ball	X 2868	0.40	0.10	0.45	0.50	--	--
IED 70-15-69	Olin Corp	Ball	X 2869	0.40	0.10	0.25	0.19	--	--
IED 70-15-70	Olin Corp	Ball	X 2870	0.40	0.10	--	--	--	--
IED 70-16-C	DuPont & Co	Extruded	CR 7814, Lot 4	--	--	--	--	0.92	0.78
IED 70-16-21	DuPont & Co	Extruded	EX 8421	--	--	--	--	0.50*	0.50*
IED 70-16-22	DuPont & Co	Extruded	EX 8422	--	--	--	--	0.25*	0.25*
IED 70-16-23	DuPont & Co	Extruded	EX 8423	--	--	--	--	--	--
			Additional Smoke and Flash Test at APG						
ATL 72-1	Olin Corp	Ball	WC 870 AL 47169	0.08	0.11	0.87	0.87	--	--
ATL 72-5	DuPont & Co	Extruded	EX 8445	--	--	--	--	0.43	--

* Approximate

TABLE III

Results of Extreme Temperature Ballistic Tests
With Cartridge, TP, 20 mm M55A2

Ammunition Lot Number	Propellant Lot Number	Temperature (°F)	Average Gage Velocity (fs)	Avg Pressure (psi)	Avg Action Time (ms)
		Loaded with Ball Type Propellant			
IED 70-15-68[1]	X2868, WC870	+70	3404	52,000	2.54
IED 70-15-68	X2868, WC870	-65	3228	46,800	2.78
IED 70-15-68	X2868, WC870	+165	3456	52,100	2.55
IED 70-15-69[2]	X2869, WC870	+70	3404	51,000	2.60
IED 70-15-69	X2869, WC870	-65	3269	50,300	2.90
IED 70-15-69	X2869, WC870	+165	3458	51,200	2.57
IED 70-15-70[3]	X2870, WC870	+70	3432	55,700	2.79
IED 70-15-70	X2870, WC870	-65	3255	47,900	3.13
IED 70-15-70	X2870, WC870	+165	3557	54,000	2.78
Control	WC870, AL45730	+70	3360	46,400	2.55
Control	WC870, AL45730	-65	3297	50,800	2.64
Control	WC870, AL45730	+165	3460	55,200	2.46
		Loaded with Extruded Type Propellant			
IED 70-16-21[4]	CR7814	+70	3404	51,200	2.73
IED 70-16-21	CR7814	-65	3220	45,100	2.95
IED 70-16-21	CR7814	+165	3526	59,500	2.64
IED 70-16-22[5]	EX8422, CR7814	+70	3356	49,900	2.71
IED 70-16-22	EX8422, CR7814	-65	3147	43,500	2.92
IED 70-16-22	EX8422, CR7814	+165	3469	56,000	2.62
IED 70-16-23[6]	EX8423, CR7814	+70	3361	50,100	2.66
IED 70-16-23	EX8423, CR7814	-65	3183	47,700	2.84
IED 70-16-23	EX8423, CR7814	+165	3458	54,600	2.55
Control, Lot 4	CR7814, Lot 4	+70	3373	52,800	2.67
Control, Lot 4	CR7814, Lot 4	+65	3270	48,900	2.83
Control, Lot 4	CR7814, Lot 4	+165	3417	54,900	2.61
		Additional Ballistic Tests			
ATL 72-5[7]	EX8445, CR7814	+70	3288	48,100	2.76
ATL 72-5	EX8445, CR7814	-65	3271	57,100	2.97
ATL 72-5	EX8445, CR7814	+165	3297	48,900	2.75
Control, Lot ATL 72-1[8]	WC870, AL47169	+70	3371	53,000	2.40

[1] 0.50% tin dioxide, 0.45% potassium nitrate

[2] 0.19% tin dioxide, 0.25% potassium nitrate

[3] 0.00% tin dioxide, 0.00% potassium nitrate

[4] 0.50% tin, 0.50% potassium sulfate

[5] 0.25% tin, 0.25% potassium sulfate

[6] 0.00% tin, 0.00% potassium sulfate

[7] 0.00% tin, 0.43% potassium sulfate

[8] only the first control lot was tested at extreme temperatures

All the photographs taken during the smoke tests are contained in reference 6. Three of these photographs are shown as Figures 1, 2, and 3.

Reference 6, together with independent reviews of the individual smoke test photographs at both the Weapons Command and Frankford Arsenal, concluded that the ammunition loaded with CR 7814 type propellant without flash suppressant and antifoulant (Lot 70-16-23) gives the greatest reduction in smoke (viewed from behind the gun). The ammunition loaded with WC 870 type propellant without flash suppressant and antifoulant (Lot 70-15-70) gives the second greatest reduction in smoke. It should be pointed out that it was expected that these two lots would give the least amount of smoke.

Reference 6 also gives detailed results of the night flash tests. In the flash test the propellants that gave the minimum smoke; namely, the CR 7814 and WC 870 types without flash suppressant and antifoulant, gave a very large and very bright flash. The General Electric Company then agreed to supply a flash hider they had developed for the M168 gun and it was decided to fire both the extruded propellant (CR 7814) and the ball propellant (WC 870) control ammunition, as well as the ammunition loaded with the CR 7814 and WC 870 propellants without flash suppressant and antifoulant. The test was fired both with and without flash hider on the gun. Again a very large increase in muzzle flash was observed with the ammunition loaded with both the WC 870 and the CR 7814 type propellants without flash suppressant and antifoulant. The flash hider reduced the flash in each case, but the flash still remained very large with the propellant not containing flash suppressant.

Fort Bliss

Additional smoke and flash tests were fired at Fort Bliss on 2 June 1971 using a towed M167 gun system. Representatives of the Project Manager for VADS, Fort Bliss, General Electric Co., and Frankford Arsenal witnessed these tests, which were performed at the Dona Ana Range in New Mexico. It was the consensus of this group that the large

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[6]Mr. Hartung, "Engineer Design Test of Propellant of 20 mm Cartridge for Vulcan Air Defense System," USA Tecom Proj No. 3-MU-005-000-001, Report No. APG-MT-3818, April 1971.

Figure 1. Gun Position and Target Before Firing

Figure 2. Smoke From Control Propellant, CR 7814, After 60 Rounds Fired with Target Obscured

Figure 3. Propellant EX 8423* After 60 Rounds Fired With Target Visible (*CR 7814 without Flash Suppressant and Antifoulant)

flash produced by both the WC 870 and CR 7814 type propellants without flash suppressant and antifoulant was unacceptable. It was impossible to adequately judge the smoke at the Fort Bliss test because of the wind and dust conditions, but the majority of the witnesses felt there was an improvement in the downrange target visibility with the two propellants without flash suppressant and antifoulant.

ADDITIONAL TEST OF PROPELLANT WITHOUT ANTIFOULANT

Just as the testing of the eight special lots was completed at Fort Bliss, Frankford Arsenal procured a sample of CR 7814 type propellant which contained no antifoulant (tin) but did contain the normal amount of flash suppressant. This sample was to be used in an existing test program to determine the effect of propellant additives on barrel life. Since the flash tests at APG and Fort Bliss proved that the propellant without flash suppressant cannot be tolerated in the present M168 gun, which had no mechanical flash hider, it was agreed that the final part of this program would be a smoke and flash test of this soon-to-be-available propellant without antifoulant. If these tests indicate that a substantial reduction in smoke was achieved by removal of the antifoulant only from the propellant, and the tests to be performed under the talc additive program indicate that the removal of the antifoulant had no deleterious effect on barrel life, then this type of propellant could be loaded into the VADS ammunition.

The ammunition for the additional smoke and flash tests was loaded at LCAAP. The description of the propellants is given in Table II. The results of the velocity, pressure, and action time tests performed at LCAAP are also reported in Table III.

It should be noted that the average velocity of ammunition Lot ATL 72-5 was slightly below the required cartridge velocity; however, this should have no effect on the smoke and flash testing.

The smoke and flash tests of the two additional lots of 20 mm, M55 cartridges were also performed at APG. The detailed results of these tests are reported in reference 7.

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[7] M. Maule, "Engineer Design Test of Propellant for 20 mm Cartridge for Vulcan Air Defense System," USA Tecom Project No. 3-MU-005-000-001, Report No. APG-MT-4149, September 1972.

The photographs of the smoke taken from behind-the-gun position in this test indicated little difference between the two propellants. There appears to be two explanations why the smoke from the standard ball propellant, WC 870, completely obscured the target in all of the first tests,[5] while in the additional test, [6] the target visibility varied from complete obscuration to visible. Table II lists the amounts of the ingredients in the two lots of WC 870 propellant that contribute to the smoke. Note that the total amount of potassium nitrate, tin dioxide, calcium carbonate and sodium sulfate (resulting from propellant processing) for the smokey WC 870 AL45730, equals 2.48 percent while for WC 870 AL47169 used in the additional test, these four ingredients total only 1.93 percent. The almost 25 percent reduction in smoke producing ingredients certainly accounted for part of this difference in test results with the WC 870 controls; but secondly, the test method which is most practical; that is, photographing the smoke as the gunner views it, is very sensitive to range weather variations such as wind, etc., and is therefore not a precisely accurate scientific tool.

The removal of the tin only from the CR 7814 type propellant does improve target visibility over the regular CR 7814 type. However, in one test the target was completely obscured. In the first tests with CR 7814 without either additive, the target was always visible.

The flash tests which were performed with a standard M168 gun without a mechanical flash hider indicated little difference between the two propellants. The flash from both propellants was acceptable.

Frankford Arsenal is presently completing two development engineering program designs to determine the effect of various propellant additives on the barrel life of M50 series 20 mm ammunition. Since these additives; tin, tin dioxide, talc, etc. also contribute to the smoke, the final results of these barrel life programs will be an important consideration in the smoke problem.

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[5] A. Victor Nardi, "Smoke Problem in 20 mm VAD System," Frankford Arsenal Quarterly Progress Reports from 4 April 1969 to 6 March 1973.

[6] Mr. Hartung, "Engineer Design Test of Propellant for 20 mm Cartridge for Vulcan Air Defense System," USA Tecom Proj No. 3-MU-005-000-001, Report No. APG-MT-3818, April 1971.

The results of the barrel life test at LCAAP with propellant EX 8445 (tested for smoke and flash) will be published in a Frankford Arsenal report describing the entire talc-additive barrel life program.

Another Frankford Arsenal report will be published describing barrel life tests of WC 870 propellant with and without tin dioxide. This report will describe the "Effect of Inorganic Additives" program.

CONCLUSIONS

1. Propellant without flash suppressant cannot be used in the present 20 mm, M168 VAD System gun.

2. Reducing the amounts of flash suppressant and antifoulant contained in the propellant does improve the behind-the-gun target visibility.

3. The use of the experimental mechanical flash hider on the M168 gun did reduce the flash. The flash was reduced with the propellant containing a normal amount of flash suppressant and the propellant containing no flash suppressant.

RECOMMENDATIONS

1. That any gun system in which smoke could be a problem should be equipped with a mechanical flash hider so that propellant flash suppressant could be minimized.

2. That engineering programs be commenced that will insure the reduction in smoke obscuration in the VAD system with WC 870 and CR 7814 type propellants, without undesirable increases in flash, through use of reduced amounts of conventional alkali metal flash suppressants and elimination of antifouling agents.

3. That improved propellant flash suppressants be developed which do not contribute to smoke obscuration as do the alkali metal salts presently used.

4. A more precise method of measuring gun and/or propellant smoke be developed.

REFERENCES

1. Teletype No. RI 33379 dated 27 September 1966, from Weapons Command to Munitions Command.

2. "Smoke and Flash in Small Arms Ammunition," September 1954, Midwest Research Institute, Contract DA 23-072-ORD-769.

3. Letter from Frankford Arsenal to US Army Munitions Command, "Smoke Problem in 20 mm VAD System" dated 18 November 1966 with 1st Ind to US Weapons Command dated 12 December 1966.

4. Procurement/Work Directive from US Army Weapons Command to Frankford Arsenal, "Chaparral/Guns," AMCMS Code 5292.12. 69702.25 dated 3 January 1969.

5. A. Victor Nardi, "Smoke Problem in 20 mm VAD System," Frankford Arsenal Quarterly Progress Reports from 4 April 1969 to 6 March 1973.

6. Mr. Hartung, "Engineer Design Test of Propellant for 20 mm Cartridge for Vulcan Air Defense Syste," USA Tecom Proj No. 3-MU-005-000-001, Report No. APG-MT-3813, April 1971.

7. M. Maule, "Engineer Design Test of Propellant for 20 mm Cartridge for Vulcan Air Defense System," USA Tecom Project No. 3-MU-005-000-001, Report No. APG-MT-4149, September 1972.